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New Information-Communication Technologies in Scientific Communication: Implications for Third-World Users

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Abstract *This paper considers the transfer process in the context of Third World needs and endeavours and suggests that modern information–communication technologies are not different from any other new technology in the economic order. The issue is equitable technical collaboration. In order to avoid past mistakes, it is necessary to consider technical change in the social context. New technologies can then be more effective tools to access scientific knowledge.*

Keywords Informatics, developing countries, technology transfer, information sector, information infrastructure.

Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in information?
—T.S. Eliot, "Choruses" from *The Rock I.*

The Transfer Process

The communication of scientific knowledge to the Third World is important to help ameliorate the worst forms of poverty, enhance economic development, increase the general wellbeing of the population, and bring about greater equity in world affairs. However, the advances of modern technology are taking place very fast. Developing countries should have a stake in these advances and make the best use of new information technologies and so participate in the solution to the world's inequities rather than be part of the problem.

The focus of information technology in developing countries has to be on the many target populations, information to and from the villages, farmers as well as researchers,

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and decision makers. The mode in which benefits are obtained from use of knowledge is important. The question of how best to communicate science and its problems in the Third World context is not a new one. In this article, I argue the importance of considering the historical causes of technology transfer because they have a bearing on the present situation. I will point out that, historically, the developing countries began under a severe handicap, giving rise to growing "technology gap." There are lessons, too, to be learned from earlier experiences in more technically advanced countries. Apart from some of the obvious difficulties presented by the introduction of new technologies generally, I will try and provide an overview of the socioeconomic and cultural implications inherent in the current "information revolution" and their importance for the communication of scientific knowledge. Economic development is basically a learning activity, which is successful when a particular country learns to make best use of existing resources, takes those most appropriate from advanced sources, and applies them in a manner best suited to the country's own priorities and aspirations. Empirical studies of structural change in developing economies increasingly are showing changes in allocation of resources toward information systems (OECD 1981).

The user of scientific information living in one of the more advanced countries, which is often referred to as the industrialized "North," can expect to draw on a vast array of information tools and methods to obtain answers to the questions posed. Libraries and information centers cater to every need. Greater access to information for everyone has largely come about by the rapid introduction of new information technologies. Efficient means of information dissemination and communication in turn facilitate growth in other sectors of the economy. We are all affected directly or indirectly by this so-called Information Age we now live in. The computer is readily accessible to a large part of the population in the North. Computers have not only acted as more efficient stores of information but also have become capable of manipulating data they contain in order to create new information. For example, a computer containing data on commodity prices and exchange rates can be programmed to indicate comparative costs in different countries in a single currency. Bibliographic data bases are also widely accessible, so that the average user sitting at home can draw on the resources of many of the world's great libraries simply at the touch of a button—and, of course, the payment of the appropriate connection charge! Added to this, there is a range of supplementary choices available to obtain really vital pieces of information including: research institutions, specialized information analysis centers, and referral centers. At a further level, one also can draw on computer clubs and users groups. The number of channels by which one can gain access to this treasure house of sources are also varied and range from professional societies, literature searches, expert systems, information brokers, to the more conventional libraries.

North Versus South

Access to scientific information in poorer countries, sometimes referred to as the "South," is limited in contrast to the situation described in the North. The South lacks the necessary infrastructure to support the types of services the North has come to expect. The new information technology has been developed in response to the demands of industrial society. At present, we are witnessing a growing gap between the North and the South, that is, those with access to information versus those who lack it. This is commonly referred to as the *information gap*, which is growing at an exponential rate in much the same way as the "literature explosion." Put the two conditions together and we are presented with a situation that is compounding world poverty just as much as any other economic factor in the development process. "Knowledge," claimed Dr. Johnson, "is of two kinds. We either know a subject ourselves, or we know where we can find information upon it." In this sense, knowledge is power—"*Nam et ipsa scientia potestas est*" as Frances Bacon (1561–1626) postulated—and, if left to its own devices, the current information revolution will reinforce the power dynamics of the current global situation, creating a permanent dependency relationship of the South on the North for access to scientific and technical information needed for development. This need not be the case, given some commitment on the part of the North to share in technological developments in the information-communication field in a manner that is more likely to permit more equitable development so that the South will be able to maintain a position in the changing world. The situation is bad, but not all that bad.

The development problem we face is complex but may be summarized thus:

- How can we provide greater access to scientific information for people in developing countries; and
- How can new information-communication technologies be effectively transferred to developing countries so that they will not be denied partnership in the information revolution?

The development issues facing poorer countries need to be matched by the creation of sound research and development institutions and capacity building. Information infrastructure is basic to this process. The principle that those who create knowledge have a duty to see that it is disseminated should apply. However, given the fact that socioeconomic, cultural, education, technical, and environmental factors are different in each country, we need to consider the following basic assumptions:

- That poor countries do not have the resources to build independent and comprehensive information systems, services and networks; any attempt to address needs in this respect will have to be based on Cooperation;
- That to escape the dependency relationship being built up on available information services in the North, a developing country will need donor assistance in acquiring the information it needs because it cannot, in the long term, rely on foreign sources to make selections on its behalf;
- That unconnected and independent proliferation of information systems and services can result in *duplication* and overlap; cooperation and collaboration make for economies of scale, reduce waste, and optimize use of indigenous resources: and
- To be effective adoption of new information technologies must be *appropriate* and adaptable to local conditions.

History of Technology Transfer

Modern economic growth has been attributed in part to the advancement of knowledge and the utilization of the results of new research. Karl Marx identified technical advances as the reason for changes from production mode to another. Schumpeter (*Theory* *of Economic Development*, 1934) considered technical innovation as the main cause for economic growth, and the absence of technical innovation as that for decline or failure. Specialists in economic analysis have placed greater importance on the role of technology transfer in explaining why some economies grow and others do not. However, these theories are somewhat controversial, and some social scientists have questioned the role of technical change in progress. Some have argued that it might be possible to describe technological shifts as a function of the market—changes in demand or profitability. It is not generally accepted, however, that such explanations would apply to developing countries where there are wide divergences, both socioeconomic and cultural, which prevent the adoption of generalist theories and which may or may not have matched conditions in more advanced countries.

One cannot ignore history, however, and examples taken from the past can provide evidence of general problems, some of which may be avoided in new situations or expediencies to permit faster adoption of practices in countries involved with new technologies. In this respect, I maintain that new information technologies are no different from any other technologies that are being transferred to a country for the first time. Technology has always been transferable from one country to another, but there are costs chiefly identified with technical, economic, environmental, and political factors pertaining to the country to which the type of new technology is being transferred. Developing countries have, on the whole, been unable to respond rapidly to new technologies because of lack of the necessary infrastructure.

In classical economic terms, many developing countries are caught in what Leibenstein has described as a low level equilibrium trap where technology and infrastructure are at such a primitive state of development that the incremental costs of modernization do not promise a sufficient rate of return to encourage further investment in capital equipment. Yet other developing countries, such as China, have been trapped at times in their history by the opposite effect. For instance, what caused the technical revolution that made twelfth century China the most advanced state in the world at the time? Why did Sung China's flair for new technology disappear so rapidly, and why did it fail to capitalize on the results of technology and, thus, spawn the equivalent of the industrial revolution in the West? The answers are complex but may be found in China's ability to keep ahead of its neighbors in basic skills such as farming and military technology, and this had a spin-off effect in other sectors of the economy. The reasons for China's technological stagnation after 1350 A.D. are equally elusive but include the paradoxical "high level equilibrium trap" whereby technology, particularly irrigation and water transport, was so perfected in traditional terms as to place a block on the expansion of per capita demand and thus discourage investment of time and money in new technology. There are analogies elsewhere in the developing world at various times. India might also be a good example of this paradox.[1]

Economic development must be based on the creation of new structures and a service sector that can provide supportive features to permit new technologies to survive and consolidate. Let me try to clarify this concept by the example of the so-called *newly industrialized countries* (NICs), a term mainly applied to some countries in Southeast Asia, Korea, Taiwan, Singapore and some Latin American countries, for example, Brazil.

In the changing economy, the information sector in these countries is given new

[1]For a fuller discussion of this, see, for instance, 1973. M. Elvin, *The Pattern of China's Past*. (London:Eyre Methuen).

prominence alongside other important sectors of the national economy. This has been described by Porat (1977) as the *primary information sector.* This sector includes goods and services that provide information or are related to the collection, processing, and dissemination of information; or are established markets. It includes not only the microelectronics industry, communications, and education but also a wide variety of goods and services. Porat also describes the *secondary information sector*, which includes in-house information activities, for example, information activities by private industry and government institutions which are not transacted on established markets.

In recent times, NIC countries have been able not only to absorb new technologies but also consolidate the experience and build on it, creating whole new industries around the original technologies. A good example of this would be the information sector in Korea which has been found to be expanding faster than any other sector of the economy. For instance, a recent study initially developed for OECD economies employing shift-share analysis was applied to the Korean economy over the period 1975–1980. The results revealed that the information sector had the highest rate of employment expansion of any macro sector. Moreover, employment in noninformation services was found to increase at less than half the rate that was experienced in the information sector (Englebrecht 1987, p. 26). Other studies support this thesis and have been carried out in several countries in the region (Englebrecht 1987 p. 20).

Countries able to do this have had in place the necessary supportive structure such as education, planning, and marketing forces which were able to provide for a skilled workforce, government intervention, and enterprenurial skills (Dahlman 1987). Such economies place a high value on exchange of information and may be called information-based societies. Transfer of technology may be said to be complete when it has been localized and utilized as an integral part of the domestic economy as import substitution (See Gaski 1982; Usher 1972). The role of integration of technology in economic growth is enhanced by the two-way flow of information, and the NICs have capitalized on this to the full. The feedback process is involved in all steps of the transfer process, (ideas; invention; awareness; adoption; adapting to local conditions; testing debugging; and acceptance). It is also shaped by the activities of change agents and information brokers capable of giving technical information, means, and consultation to industry. The main issue for many developing countries, especially the poorer ones, really lies not in acquiring new information-communication technologies but rather, in acquiring the capability to use existing technologies more efficiently, to use the experience in investment to adapt and improve technology in use. The main path toward the goal will be to build on affordable and viable technologies from abroad while developing local capabilities for repair and maintenance and training programs. Because all capabilities cannot be developed at the same time, the sequence of events in which technical capacities are developed will be crucial. These capabilities change with national priorities. Selectivity must be the focus of national information policy, based on feedback from application (Dahlman 1987, p. 762).

Change comes about in many ways, but the successful countries at some point have begun to put in place the necessary building blocks in the economy that will support the advances thought desirable. There is a change in the level of industrial and entrepreneurial activity closely linked to technical change. In the case of information technologies, the very earliest examples can be pinpointed to the introduction of printing. The Gutenberg revolution was a major factor in the spread of knowledge.

> He who first shortened the labour of copyists by device of movable types was disbanding hired armies, and cashiering most Kings and Senates, and creating a whole new democratic world.
>
> —Thomas Carlyle (1795–1881)
> *Sartor Resartus* Bk., i Ch. 5

The rate of recording information increased after printing was invented, largely because someone saw the economic benefits of publishing books. Printing created income, profit increased and hence, it became increasingly attractive to greater number of people. The concept I wish to emphasize here is one of income generation as an important factor in technological change. We are all familiar with the Industrial Revolution, which first took place in Britain, followed later by the United States, then by other European countries, and finally by Japan at the beginning of this century—there being a distinct relationship between the flow of goods and services between countries (Tuma 1987, p. 407). This has been referred to by some analysts as the "bandwagon" effect. This effect has also often been accompanied by breakthroughs in energy, transportation, and electronics. Countries that were slow to join the bandwagon effect found it harder to do so the farther up the road the bandwagon went. In Europe, late developers, typified by countries with a traditional agricultural sector, such as France, Germany, Poland and Russia, Spain, and Portugal, also lacked the supportive structures. Developing countries, hampered by colonialization, could not get on the bandwagon at all and, it may be said, as a result they were never properly in the race.

The technological gap has since been allowed to grow dangerously wide to the point that it may even be irreversible. For instance, in 1800, British industry had 5–6% new technologies while its colonies had less than 0.5%. By 1830, Britain had rapidly increased its share of new technologies to 32–40% of its total industrial sector, yet the colonies lagged at less than 1%. By 1900, when Britain had achieved nearly 80% new technology, the colonies still had less than 10%. Thus began the dependency relationship, where the developing world became increasingly reliant on the industrialized world for technical solutions to its problems. This dependency relationship has continued to grow. It is particularly applicable to the problem of information sharing and the introduction of new information technologies.

The continual widening of the technology gap and increasing dependency relationship between countries of the North and those of the South has been intensified by economic forces and the growing indebtedness of many developing countries. People in developing countries earn low per capita incomes. According to a recent World Bank report, 87 out of 129 countries earn less per capita than one-fifth of the per capita income of industrial countries (World Bank 1988).

Most developing countries are agricultural economies and have to rely on surplus products from the agricultural sector to provide cash to purchase inputs of foreign technology. Very few poorer countries have agricultural surpluses and are food deficit countries. Foreign exchange simply is not available for capital investment.

This situation is also most acute in African countries where information technologies are now considered by some writers to be along way ahead of local infrastructural requirements (Ochai 1984). The lack of income and corresponding low levels of investment stunt growth in research and development. The World Bank (1985, p. 10) highlighted this in a recent report, which extrapolated the numbers of research staffs available by the year 2000 based on the percentage of Agricultural Domestic Product (AGDP).

The above table sets out three scenarios of agricultural domestic product (AGP)

Table 1
Projected Number of Agricultural Research Scientists Required for National Systems, Sub-Sahelian Africa, to Year 2000

	Percentage of AGDP to Research	Number of Agric. Scientists
West Africa		
Scenario 1	1.00	14,000
Scenario 2	.67	10,000
Scenario 3	.33	5000
East Africa		
Scenario 1	1.00	15,500
Scenario 2	.66	11,000
Scenario 3	.28	6500

Source: World Bank Development Report on Africa.

dedicated to research. Scenario one represents the most opportunistic prediction, but the study suggests many African countries will be hard pressed to even meet the figures in scenario three. Thus, the total number of scientists trained locally for the whole of sub-Saharan Africa by the year 2000 will be somewhere between 11,000 and 12,000. (These figures do not include replacements for existing expatriate, core universities, or parastatal staff.) This is a grim situation and is further evidence of the continued dependency relationship in the North for key research posts. Information programs are affected by this serious situation, and African countries must pay attention to the resources necessary in planning information systems and services, especially the capacity to define the situation and the problem of information transfer before the adoption of new information technologies (Stone 1985).

The existence of a buoyant capital goods market is also an important determinant in the transfer of technology in terms of both absorptive capacity and motivation to provide upward pressure to continue the pattern and rate of change. According to Rosenberg (1976, p. 164) the creation of an industrial base is a means for institutionalizing internal pressures for the adoption of new technologies. Where this pressure does not exist, transfer rarely takes place. This is well illustrated in developing countries where weak internal forces fail to garner sufficient power locally to muster changes in the technical environment. This is particularly true in the case of the library and documentation situation in developing countries. Some countries, such as India have strongly developed national information policies and professionals able to some extent to form a strong enough lobby to affect some degree of change (Kumar & Attri 1987). Contrast this with the African situation, where lack of trained human resources fails to create the demand and keeps up the pressure for new technologies. The overall picture of the internal constraints on transfer of new information technologies has been summarized by Eres (1980) and is adapted in Table 2.

The factors suggested by Eres would tend to seriously inhibit the transfer process. To sustain the progress would be difficult, but surely the problems associated with social, economic, cultural, and political constraints are not inseparable. The opportunities presented by new information technologies suggest that it is important to look for adjustments. Nevertheless, even with such constraints there are possibilities for success-

Table 2
Factors Inhibiting Information Technology Transfer

General Factors	Conditions in Developing Countries
Economic	Labor intensive society; Low availability of capital; Inability to absorb recurring costs; Expense of international activities; Lack of internal competition; Problems with foreign exchange regulations.
Manpower	Lack of available trained manpower; Low prestige of information, professionals; Difficulty in recruiting specialists; Lack of continuing education.
Physio-ecological	Limited resources; Geographic isolation.
Cultural, demographic, & social	Large percentage of unskilled workers; Language barriers; Fear of modern technology; Inaccurate expectations of technology; Information-seeking behavior of scientists and technicians, especially its low priority.
Political	Unstable governments; Desire for often excessively tight security and secrecy; Constantly changing priorities; Centralization of decision makers; Lack of scientific impact at highest levels of government.
Existing information	Poor quality of telephone service; Inadequacy of postal service; Tight, stringent customs systems; Inability to join telecommunications networks; Lack of liability and information standards; Insufficient hard-copy collections; Absence of sufficient informal information flow.

ful transfer of technology and there are many other factors that can be attributed to success or failure, such as the existence of good (a) communication, (b) cooperation, (c) management, (d) planning and control, (e) participation, and other (f) control features.

It is possible to measure success or failure in quantitative terms using efficiency standards developed by economists for industry or firm levels of aggregation using linear programming and linear regression techniques. For the information industry, *efficiency* is a relative term, since it should be measuring non-allocative efficiencies, or what Leibenstein called "X" efficiency. Such studies have been carried out on a number of developing countries, for example, Ghana, Tanzania, Thailand, for various industries. It is, therefore, misleading to make generalizations about success and failure in the developing country context without adequate analysis in a given situation.

In the broadest sense, however, the problems facing countries of the South today are very serious indeed. Beginning the race under handicap, the backlog of forces have become formidable hurdles to overcome. Current high costs of new technologies are an increasing burden on countries lacking foreign exchange. Many developing countries are conscious of the fact that to introduce technologies and develop their economies, investments have to be made in education and advances in general literacy levels. In promoting education, some countries such as Ethiopia have run into problems with a rising educated youth now facing employment problems. The local economy cannot absorb the expansion in numbers of educated people. Because of lack of necessary improvements in other relevant sectors, school graduates cannot be gainfully employed in industries able to use their skills. Unlike the NICs described above, the necessary infrastructure is not in place. Ethiopia is a good example where the human skills exist, but the corresponding value added in terms of capital goods industries for new technology do not exist. Several problems have plagued Ethiopia, apart from policies in general. With regard to education, the student population has increased more rapidly than state budgets for science and technology facilities. Libraries and information services have fared particularly badly. There is a ready supply of librarians but too few libraries to work in, and those available lack the tools to work effectively. It is one thing to train people and another to put trained staff to use. A serious result of this is that those who can leave do. The "brain drain" of educated staff from developing countries to international organizations and to industrial countries is a growing fact. Under this situation, developing countries continue to be consumers of scientific information rather than producers. For instance, between 1963 and 1976, Arab countries established 567 new projects, but virtually in none of them was there any technology transfer in the sense of acquiring the knowledge and skill to maintain and do it themselves independent of expatriates (Tuma 1987, p. 420).

It is often said that markets in developing countries are too small for effective transfer of new technology. Demand is too weak. This is very important in terms of information. Since no information service is cheap, high costs will accrue to storing and disseminating information to users in developing countries. New technologies to ease the job will also be very costly. We should not forget the following quote: "Grace is given by God, but knowledge is bought in the market" (Clough 1819–1861). Foreign exchange is simply not available to purchase either the technology or data bases to run it. In other words, the transfer of new information technology incurs a cost that puts the developing country at a comparative disadvantage. This may be true in the short term, but only if the market were perfect. It is not, as described above. Therefore, no country can hope to develop and advance technology simply by accepting short-term comparative advantage. Most countries try to protect infant industries especially under threat of competition. The case for comparative advantage is linked to vested interests and political advantage. Developing countries are highly susceptible to package deals for purchase of technologies from industrial countries in the form of tied aid, kickbacks, and economic promises of various kinds. A shift to basic production would disrupt international commercial operations. Therefore, the dependency relationship is firmly entrenched with modern market forces which have nothing to gain from the transfer of technology to developing countries. The role of donor assistance has to be carefully prioritized and implemented to avoid compounding the dependency relationship. Assistance to information projects will fail if attention is not paid to implementation procedures and sustainability. A minimum of 10 years must be budgeted to firmly entrench a research and information system in a developing country. One has to consider that start-up costs are necessarily higher than ongoing costs. A team has to be found and put in place. Time must be allowed for the parent institution to become able and willing to bear the cost of running a service. Projects will fail where the technology is carelessly selected and where the project is badly planned and managed and is not coordinated locally according to national priorities. Very often decision makers seek out assistance from donors without a real appreciation of all the factors on which success will be based. Development best succeeds when society learns to make optimal use of its resources through application of science and technology to improve the living conditions of the population in ways consistent with national needs and priorities. In consideration of this, it is very important to devise the means by which information and science and technology reach the ultimate beneficiaries and are not limited to urban elites in developing countries.

New information-communication technologies for use in developing countries must, therefore, be applied with the ultimate beneficiaries in mind. Otherwise, we run the risk of recreating the dependency relationship at the national level—rural poor dependent on the urban rich. To obviate this situation, micro-information environments should be considered at the grass-roots level to ensure the all-important feedback loop is closed. By giving the poorer sections of the economy a share in the information process, we ensure not only a more equitable distribution of resources, but also create a situation whereby technology is applied correctly and viably. For this reason farmers, small-scale enterprises, and village level workers require access to modern telematic facilities, including radio and satellite stations, microcomputers for field use, and such other tools as may be deemed appropriate in a given situation; for example, compact libraries utilizing compact disk read only memory (CD-ROM) at the village level. Television is now an almost universal medium; therefore, use of video to demonstrate techniques has much importance in some extension programs. *Who* determines appropriateness and *how* technology will be implemented are the two key issues. Emphasis on bottom-up development will, hopefully, encourage the local pressure group for change at the decision-making level to successfully lobby for technical change. Strategies designed and created at the center can only influence the periphery so far. The periphery needs to be activated and informed to maintain a momentum in the development process.

What Technology?

> 'Knowledge advances by steps and not leaps'
>
> —Lord Macaulay, *Essays and Biographies, History* (1828)

By emphasizing the question of national acquisition of new information technology, not enough attention has been given to what kind of technology should be acquired and who will use it. Much depends on the trade-offs between capital expenditures, training, research, and education generally in terms of time scales. More detailed attention should be paid on the impact at the institutional and human level.

Information technology has been around a long time. Each new technology has had profound effects on the society involved in its transfer. It began with our first efforts to record ideas, and evidence is found in the earliest civilizations. In China over 3000 years ago, attempts were made to systematically record knowledge on the oracle bones. Today, when we talk about the information-communication revolution, we are increasingly talking about new tools and methods to handle information—a combination of computer-based technologies, microelectronics, telecommunications and space technology; in other words, we mean mechanized methods to collect, collate, store, retrieve, and disseminate information. A partial though not exhaustive list of such technologies might include:

- Computer graphics,
- Computer conferencing,
- Computer-assisted software engineering (CASE),
- Desktop publishing,
- Expert systems,
- Geographical information systems (GIS),
- Local area networks (LAN),
- Machine-assisted translation,
- Management information systems (MIS),
- Optical and computer disks (CD-ROM),
- Packet switching,
- Remote sensing and satellite imagery, and
- Telecommunications (FAX, e-Mail, *etc.*).

Some or all of these technologies are now in widespread use in many industrialized countries. From the developing country point of view, we need to focus on those that are likely to have value, are transferable, and can be viable under local conditions. At this point I will examine a few of what we might term *technologies of promise* and provide some examples of their utilization, problems as well as prospects.

Microcomputers

The one technology we tend to think of as "new" is the microcomputer. Microcomputer use in developing countries is not really new. Computers have been in use in developing countries for some time with success.[2] Microcomputers are now quite widespread. Recently, it has generally been thought by some that the introduction of microchip technology would be the means for accelerating growth in developing countries by "leapfrogging." This optimistic theory was popularized by such writers as Arthur C. Clarke (1981), Toffler (1980) and Soete (1985). It suggested that the industrial revolution could be bypassed by developing countries for an information society, which is decentralized, increasingly innovative, and independent of transport with product substitution. Opposed to this was a group of experts who postulated the "grey skies" theory, such as Hilling (1979) and Forester[3] who warned of such limitations to transfer of new technologies because of such impediments as licensing agreements, restrictive practices, and the infrastructure gap. Neither theorist has been exactly correct. Microcomputer use has become increasingly widespread in developing countries, yet it has not achieved the dramatic breakthrough predicted by writers such as Clarke. In practice, it is neither theory; rather it is as Lord Macaulay said; "Progress is a stepwise process," what we may also call the "trickle down" effect.

The enormous increase in reliability and environmental tolerance of the PC, together with the wide range of software alternatives, has slowly but surely put a power-

[2]See S. Nilson, "The Use of Computer Technology in some Developing Countries," *International Social Science Journal* 31, 3 (1975), 513–524, where it is stated mainframes have been used since 1960 including in Africa.

[3]T. Forester, "The Myth of the Electronic Cottage." *Futures* 20, 3 (1988) 227–240 who has also argued that psychological problems have been underestimated and that users have not found new information technologies cheaper or more convenient.

ful tool in the hands of the developing country researcher (Toong & Gupta 1982). Some have been tested and applied in extreme field conditions and have been designed to provide rapid answers to questions posed by farmers seeking a variety of information on crops and cropping systems along the lines of "What should I do if. . . ."[4] With the successes abound failures.[5] The introduction of microcomputers has not, however, been general among developing countries. Despite their universal appeal and relative low cost, the level of computer use in Africa remains less than 5% of the world's total. Nevertheless, decision makers in African countries, as in other developing countries, are rapidly implementing computer literacy programs, and almost every developing country has some involvement with microcomputers for economic development.

Given the transfer of computer technology for information management, the microcomputer can be a powerful tool in the development efforts of poorer countries by raising the level of communication at the basic level. The transfer of microcomputer technology must be approached carefully. Care and attention must first be paid to the local environment. It is important to improve the collection and handling of data and the training of staff. The problem of trained personnel is often pointed out as the most critical factor in the introduction of computers along with staff acceptance. Other factors include the provision of adequate funding, lack of software locally, poor administrative and service backup, and lack of knowledge about the appropriate equipment for a given situation. In such a situation, education and training, as well as knowledge of the user community, is highly desirable.[6] Far too often, administrators are more keen on the prestige effect of having the latest equipment rather than approaching the problem from the job the microcomputers will be expected to accomplish efficiently according to a procedure analysis to improve the flow of data compatibility, standardization of work flows, and retrieval mechanisms). A major mistake often found in the developing country situation is that of too much too soon. It is more important to begin with a modest system and expand rather than attempt to build in a large unworkable, unrealistic system from the beginning. More sophisticated technology can be added later. An incremental approach has the advantage of having opportunities to take advantage of later development, upgrades, and so forth.

Low cost microcomputers are ideal tools for solving the myriad problems formerly handled on behalf of developing countries by computers in industrial countries. For example, it was recently postulated that the increasing indebtedness of developing countries could be better controlled if greater control was exercised over methods of recording, handling, and analyzing information to a particular country's overall borrowings. The Commonwealth Secretariat studied the situation pertaining to a few developing countries for some time and came to the conclusion that an appropriate computer-based program using available microcomputer technology could help allevi-

[4]See, for instance, D. M. Etherington & P. J. Mathews, *MULBUD, A Computer Package for the Economic Analysis of Multi-period and Multi-enterprise Farm Budget.* Canberra:Australian National University (ANU), 1984.

[5]According to one expert, the microchip could well distract the attention of Third World people from the issues of development. Attention should be paid to existing information, systems and efficient data collection. Efficient data collection must precede the introduction of a computer system otherwise disaster will result. See C. Raghavan, 1988. The Barefoot Microchip. Treasure Chest or Pandora's Box," *UN Development Forum* (March): 6.

[6]See, for instance, Ta Huu Phong, 1987. Computers in Forestry Research in Asian Countries. *Journal of the Society of Research Administrators* (19)1: 13–15.

ate some of the problems. In a series of projects, the International Development Research Centre (IDRC) supported the development and initial testing of the software comprising a system called CS-DRMS along with the training materials. This system was launched as a pilot project in Sri Lanka and other countries with some success (IDRC 1987, p. 11). The microcomputer is also now highly suitable to a wide range of statistical uses including analysis of census data. For instance, the IDRC also assisted the Latin American Demographic Centre (CELADE) in Chile to develop a microcomputer-based software package for the creation, storage, and retrieval of small area census data. Project participants are producing program documentation and user manuals in both Spanish and English and testing the software in the Caribbean as well as Latin America (IDRC 1987, p. 11). Microcomputers are also an important training tool for researchers, librarians, and teachers. Used interactively to enhance learning abilities, microcomputers can replicate the course material, as well as modify and customize it according to individual requirements (Papagiannis, Douglas, Williamson, & LeMon 1987).

Telecommunications, Computer Conferencing, Electronic Mail System

The use of the computer for transmitting information is not new, but its rapid application among the general population worldwide places it at the forefront of new information technology. Because on-line transmission of information is a tool accepted by the public at large, its transfer to developing countries is likely to spread fast in much the same way as portable radios. The transfer of this technology is also given a boost through local self-help mechanisms such as user groups and computer clubs. The transfer of this technology is also helped by public acceptance and enthusiasm for private exchange of information. Bulletin Boards are very popular. It has been estimated that upward of 50,000 may be in use worldwide. However, serious systems probably number 5000, the majority of which operate in North America (*Smithsonian Magazine* September 1988). Such systems provide an instant window on the world or a soapbox for the general public. On the scientific level, there are many boards such as Scinet, Omnet capable of putting a wide range of scientists in touch worldwide to compare notes on such issues as the global warming trend, the effects of acid rain, or the Grand Unified Theory of theoretical physics. This is the ultimate invisible college in action. Bulletin Boards can also be a powerful educational tool. Classrooms can go on-line and can connect abroad. use of the computer as an educational tool is not, however, without problems, especially when one considers cultural questions.

Computer-based conferencing systems are a further refinement of this concept whereby groups of researchers located far apart can discuss a common topic, share ideas and dialogue pretty much as one would in a physical meeting (with some limitations). The key to this is the use of the computer to store and retrieve conference content in what we term as asynchronous nature. Unlike the Bulletin Boards, where users can communicate in both real and nonreal time, conferencing participants usually communicate using the computer in nonreal time. The obvious advantage of this is apparent when one has to consider researchers located in different time zones being able to communicate and carry on with daily routines being relatively free of busy telephone lines. Moreover, it reinforces the invisible college by keeping people working in the same field in closer contact than would be possible by rare face-to-face contact. Computer conferencing, however, works best when a particular problem is the focus of the need to communicate, thus ensuring that triviality is avoided. The problems identified in developing countries that have hindered wider application of this medium include:

- Poor local facilities especially telephone links,
- Lack of access to reliable equipment,
- Lack of training and access to training materials, and
- Poor institutional support

As an example of the situation facing a developing country, a pilot computer-based conference system entitled the Bioconversion of Lignocellulosics was supported by the IDRC. Over 100 researchers participated in an 8-month activity (May–Dec. 1983).[7] The conference operated on two systems—Electronic Information Exchange System (EIES), Newark, New Jersey, USA; and COM out of Stockholm, Sweden—participation being through either system with exchange of information between both. However, one developing country participant located in Guatemala (*Instituto Centroamericano de Investigacion y Technologia Industrial*—ICIATI), had substantial equipment problems, for example, modems, cables, and software. The major problem experienced by ICIATI was lack of a good link locally to the international data transmission networks, a perennial problem experienced by many similar institutions in other developing countries. When it was eventually able to link up with the international network, it proved to be quite costly utilizing regular voice channels. However, transmission costs have to be balanced against travel costs and work disruption. The benefits, from a scientific viewpoint, may be said to have outweighed the high cost of participation if one considers that: (a) knowledge increased significantly about the subject (current thinking); (b) their own research results were confirmed; (c) the "invisible college" was consolidated; and (d) future participation in international data transmission networks was enhanced.

Computer-based messaging systems (CBMS) or electronic mail (e-mail) is beginning to have an impact on telecommunications in some developing countries. The system basically works by passing messages between different computers. One computer exists as a central node or "depot," collecting and distributing all messages. By logging-in, a user is automatically informed if mail is available. The mail can then be read on the computer and, if desired, can be copied to other users. Other options include connection to data bases and bulletin boards. The means of access to e-Mail facilities is by the microcomputer with relevant software and modem. The main advantage lies in the relatively low cost of the technology. In industrialized countries, and increasingly in some developing countries, CBMS can be reached by a telephone call. The international data network is expanding rapidly. In the past two or three years, several countries in Southeast Asia and Latin America have set up data networks. Rates have been reduced. For instance some network providers in the Philippines halved their rates in 1987. Those not able to connect to a network require a telephone call, which is a problem in many developing countries. But better modems with higher speed and error correcting devices are helping to overcome this constraint.

National research institutes in developing countries are not able to participate as

[7]D. Balson, 1985. *International Computer Based Conference on Biotechnology. A Case Study.* Ottawa:IDRC, provides a detailed account of this experiment.

much as one would hope. Local scientists tend to have less exposure to computer technology and can't obtain technical help, although local user groups are growing. They also tend to have a smaller batch of international messages to handle, and naturally, almost all have little access to foreign exchange or local money to invest in CBMS. The situation varies in each developing country. Some scientists are situated in very remote areas, particularly in such places as the Sahel. Attention, therefore, must be given to different equipment and services that might be appropriate to enable more of them to link into a network. Donor attention is needed to this aspect of telecommunication facilities in developing countries. Solutions focus on the provision of fool-proof and user-friendly equipment, most probably best depicted by the lap-top computer because of its immunity to power disruptions and its portable nature.

The system would need software utilizing a simplified set of commands, most of which would take place when the system was not connected to the network, coupled with a mechanism to call up the user if it is not possible for the user to communicate with the system. The main constraint is start-up costs and experience. The service would need to operate in areas likely to be economically viable with a demonstrated demand. In Africa, for instance, a collaborative effort involving several remote locations would be necessary to develop a system. Such a system might "piggy-back" on existing systems such as CGNET (e-Mail communications service for international agricultural research organized by the Consultative Group on International Agricultural Research—(CGIR).[8] The project was completed in 1984 and resulted in the linking of some ten international agricultural research centers located in different parts of the developing world in a network mode, along with some of their remote outreach programs with which they conduct research. It is expected that as the system gains experience, it will be able to expand and include more remote sites in the developing countries.

Packet Satellite Communication

A further spin-off from space technology has recently become available by use of low-orbiting satellites. A major cost factor in satellite communication has always been in launch costs. Those satellites which go higher into orbit stay up longer and, therefore, have a longer life. However, they are correspondingly more complex and, therefore, costly. Recent experiences in some countries with launch capability have shown the cost-attractiveness of satellites put up into lower orbits. Though such satellites drop to earth sooner, they are ideal vehicles for computer-based messaging (Ramani & Miller 1982). What this might mean for developing countries can be illustrated by collaboration between the volunteers in Technical Assistance (VITA) and the Radio Amateur Satellite Corporation (AMSAT) who in 1982 developed packet radio technology (PACSAT). This system was designed to improve communications in developing countries using low-cost and simple methods while aiming to provide a high volume of information transfer (Williams 1982).

Because it was not dependent on land-based telecommunications, universally experienced as the major limitation to communications in developing countries, PACSAT was intended to open up a new era in cheap, relatively free flow communication in remote areas of developing countries. The system uses a small earth orbiting satellite which covers each point of the earth twice daily and is capable of acting as an elec-

[8]Telematics International. CGNET: A Data Transfer Network for the CGIAR. Unpublished report submitted to the CGIAR and IDRC, November 1984.

tronic mail box, receiving, storing, and disseminating messages in nonreal time. Real time communication is also possible at the points where the satellite connects to ground stations. PACSAT holds promise, but it is not without problems. Logistical problems aside, there are legislative hurdles to be overcome, bearing in mind the highly politicized nature of telecommunications technology in some countries. In some countries, bureaucracy also provides a barrier to the transfer of this technology since telecommunications often involves the decision and authorization of several ministries, not least of which is the military.

Expert Systems

Use of the computer to mimic the mental processes of human beings has provided experts with a fascinating area of research for some time. Originally contemplated as an offshoot of research into artificial intelligence (AI), expert systems are knowledge-based programs capable of using data, a knowledge base, and a control mechanism on problems of sufficient difficulty that significant human expertise is necessary for their solution (Yaghmai & Maxin 1984). If one reads the literature on expert systems, on the whole it is optimistic. There are many successful applications in use mainly in the medical and legal fields, where abundant textbook solutions or precedents exist for seekers of information to follow. However, there are not too many results in information science. Current research using expert systems in automatic cataloging, for instance, has had mixed results (Meador & Witting 1988). The National Agricultural Library in Beltsville, Maryland, USA has a project to use a microcomputers-based expert system to help users get answers to specific agricultural questions. It is a small system built around reference texts likely to contain most of the answers people will be looking for. The system is linked to external programs providing on-line access to data bases of bibliographic citations (AGRICOLA both in BRS and DIALOG) and full text files that can give reasonable answers to basic questions rather than simply referral to set texts (Waters 1986, p. 209). The more sharply defined and simple a question is, the more likely an expert system will be able to successfully anser it.

The advantages and disadvantages of such systems may be summarized as follows:

Human Expertise IS	Artificial Expertise IS
perishable	permanent
difficult to recall	easy to transfer
difficult to record	easy to record
unpredictable	consistent
expensive	affordable

In addition to these factors, we also have to consider the more pessimistic view of the human versus artificial intelligence inherent in such systems as follows:[2]

Human Expertise IS	Artificial Intelligence IS
adaptive	unoriginal
sensorially experienced	narrowly focused
broadly focused	symbiotically input
commonsensical	technically based

Adapted from G. Lindsay, K. Novak, and R. Bilodeau, 1988. Information Technology in International Agricultural Research: Where are the payoffs? Paper presented to the *Annual Meeting of the consultative group on International Agricultural Research (CGIAR),* World Bank, Washington, DC, (1988), p. 18, (Quoted from original paper by Waterman 1986).

In the developing country situation, expert systems have been examined and found to be very useful, especially where access to expert advice is quite remote. A workshop sponsored by IDRC at the International Rice Research Institute (IRRI) in 1988 came to the conclusion that the greatest hope for expert systems in developing countries in the agricultural research area lies in provision of the missing elements in current information-communication of science and interface between researchers and the beneficiaries (Wilson 1988, p. 8). However, to make optimum use of such systems developing countries (in this case those of Southeast Asia) would have to share resources, particularly product knowledge (Wilson 1988, p. 11).

A major problem will always be in selecting the appropriate technology and adequate training of users, backed by user needs assessment surveys or end-use analysis. The practical uses of expert systems to developing countries lie in giving greater access to reliable relevant information from outside that can be used locally. Resources that previously might not have been considered possible to consult can be used. links to CD-ROM, of which more will be said below, would make this technology an imaginative tool for national research and information systems and extension workers in developing countries. Greater delegation of work to junior staff might be possible, since the junior research may be able to get further along in research without resorting to higher authority. As a training support, expert systems have an even more viable use (Wilson 1988, p. 19). Since expert systems explain their reasoning as they are used, they can help by establishing theory and relating this to practice by combining it with examples in use.

Optical Disks and CD-ROM

Of all the technologies of promise listed above, CD-ROM is probably the newest information technology that is widely known in developing countries. As a concept it has potential for developing countries and especially for those researchers working in remote areas with little hope of on-line access or other means to obtain information. CD-ROM has already been put into use, and pilot projects and experiments have been carried out to test the applicability of the tool in developing countries. For instance, the IDRC supported an 8-month evaluation in six developing country sites. A prototype product was used containing 14 months of bibliographic information and abstracts on agriculture. The evaluation showed universal acceptance of the tool (Beaumont 1988).

Compact disk—read only memory (CD-ROM) was developed from audio technology. It permits the storage of enormous amounts of information on a small, durable disk. Each disk can hold data that would require 1500 floppy disks for the same amount of information. The information is first digitized, then optically accessed. The main advantage is the virtual indestructibility and error-free data, unlike magnetic-based systems. In-depth indexing permits access to a large amount of material in a relatively short time. From the developing country point of view, all that is needed to utilize CD-ROM is an IBM-compatible microcomputer and a CD-ROM reader, such as a record player, an interface card, and cables and disks based on HSG. The process, however, is not cheap, nor are the outputs at the present time.[9] These are probably the two most limiting factors as far as developing countries are concerned. The process first requires the collection of literature to be put on the disk. If the literature is spread over a wide area and not in a single library, acquisition may be a long and costly activity. The literature is then digitized, and a glass master is made. The up-front costs are very expensive, and even though processing costs have come down recently, they are not exactly cheap. hence only large, commercial companies with a stake in the information industry in industrialized countries have so far had the resources to commit to the procedure. The cheapness of CD-ROM lies in the production of additional disks after the first master. This is why the audio industry, with its volume of sales, was able to capitalize on the CD-ROM medium as a profitable venture.

The advantages for developing countries lie in providing access to large amounts of data relatively cheaply and easily. A mile of shelving of conventional technical literature can be conveniently reduced to about a foot of shelving for disks. For a developing country remote from normal access to scientific literature, such a tool promises unprecedented access to relevant data bases. Creation of data sets in convenient form will help researchers interface their subjects more easily than ever before. Perhaps the most exciting possibility of CD-ROM technology lies in its use with expert systems. Although most information retrieval systems are adequate as a means for directing researchers to their topic and ultimately to answers to their questions, expert systems provide a quicker and more qualitative means of answering the researcher's questions. Such an interface would prove most useful in answering "how" and "where" questions of research. For instance, in crop and cropping systems research, a question about inter-cropping might be about how much shade could be expected to affect a crop grown under the shadow of another crop. By creating a data base that combined prior research results with data sets on relevant trials and a user interface that mimicked an expert on the subject, research time could be substantially reduced.

The disadvantages for developing countries have to be considered. Although cheap for use in industrialized countries, this is not so for the vast majority of developing countries, unless donor support is forthcoming.

Start-up costs for hardware and software, consisting of a microcomputer CD-ROM reader and accessories are estimated to be about US $8000. These costs will be reduced to about US $3000 if a suitable IBM-compatible microcomputer is available or an up-

[9]The High Sierra Group (HSG) provided the first standard format for compact disks in 1985. In future, as methods improve, new standards such as CD-ROM XA will permit developers to provide multimedia products and so combine audio visual and graphic output on one disk. While the technical production process is estimated to be about $10,000 for several hundred disks, additional disks could be cut for as low as $2. However, information processing costs and software development must be added to these costs.

grade is necessary. However, lack of foreign exchange often precludes some countries finding even this small amount of cash upfront. However, the major limiting factor for developing countries will be on-going costs and the high cost for subscriptions to data bases on CD-ROM, if they are available.[10] The annual subscription to the Aquatic Sciences and Fisheries Abstracts (ASFA) is $2070. CD-ROM is a read-only format, so updating of information is not possible. The medium is best suited to researchers retrospectively. As an alternative to on-line searching, CD-ROM shows promise. However, to date, not only have the high cost of subscriptions been a barrier but also the lack of suitable data bases on compact disk tends to preclude wider application in developing countries. The major data bases so far have tended to view CD-ROM as competitive with their hard copy sales (Churchill 1988, p. 42).

CD-ROM, as a medium for dissemination of information, works best when the data doesn't have to change much. Because it is read only, adding or updating the disk is not possible. Data bases issued monthly are not really cost-effective unless heavily subsidized by other services. CD-ROM, therefore, is ideal for compact libraries where all kinds of reference materials, key texts, encyclopedias, and dictionaries can be put onto one or two disks. For remote libraries, this would seem to be the most promising feature. However, compiling such a compact library on CD-ROM requires a large investment.

Developing countries experience grave difficulties obtaining copies of original documents. One answer may be in a project that has been under experiment for the past several years whereby publishers supply their scientific journals in machine-readable form for document delivery centers to print out individual articles on demand, and in the process obtain some income from interlibrary loans. I refer to the Adonis project now in its seventh year of development. The project has had many difficulties, including publishers pulling out of the project and inadequate technology. However, according to recent reports, the project is now making progress (Campbell & Stern 1987). Trials are based on biomedical literature using CD-ROM. Articles are retrieved by optical disk and are then laser printed. As a future new technology, if successful, this form of document delivery could revolutionize developing country needs. The problem is cost. At present, only very large centers can be cost-effective, and an independent study at the British Library Lending Division indicated that the economics of setting up a document delivery center from disks did not offer a distinct advantage on existing manual methods (Campbell & Stern 1987, p. 91).

After reviewing some items of new information-communication technologies, it is appropriate to discuss how they fit into the economic development of poorer countries in terms of actual needs and requirements as opposed to perceived needs and requirements. Developments in technology and their impact are hard to predict because of the complexity and because recipients of new technologies react differently in various settings. A particularly important undertaking at the national level will be credible synthesis of

[10]There are several large bibliographic data bases for the sciences listed in the *CD-ROM Directory*, 2nd Edition, K. Churchill Ed., London:TFPL Publishing, 1988. The average cost is about $2800 annually. However, the most persuasive argument we have today for decreasing the dependency relationship of the South on the North for sources of information relevant to development is the repatriation of scientific literature by emphasizing national and regional information sharing of local information. Much of the information on the CD-ROM at present relates to industrialized countries and the per unit cost of relevant local literature on these data bases can be expected to be quite high, a view also echoed by Beaumont (1988, p. 14).

economic planning and scientific research related to policy issues as a necessary precondition of adoption of new technologies. This is especially important considering the fact that relevant information about adoption and use is almost always scattered or hard to obtain.

At what point in the technology revolution should developing countries jump in? Since technology is a moving target, each country will need to judge by individual needs. There is an inherent danger that because of particular circumstances in a given country, a wait-and-see attitude is adopted. The positive and negative aspects of CD-ROM in the developing country context is a good example of this. If we consider that floppy disks are to computers what the old 78 rpm records were to the phonograph, compact disks can be expected to quickly send the old phonograph record into oblivion. Within the next 5 years or so, mechanical disk drives could also be replaced by data storing microchips. Instead of just using the microchip to process information, so the reasoning goes, why not let them store it too? Current developments include the new Dynamic Random Access Memories (DRAMS). Until recently, solid state memory had only a few specialized uses. Developments are so rapid that a new type of chip is already in use that holds out much more promise for the information industry than DRAMS. It is called the "ferro-electric random access memory." Permanent memory is a big advantage over DRAMS and ferro-electric components give signals ten times faster and so it goes on. Does this mean we can soon discard disk drives?

A hundred years ago new technology was well spaced and much heralded and took many years to perfect. Currently, new technology abounds, then survives a few years before being pushed off the shelves by newer products. It is doubtful that in 100 years anyone will ever remember the compact disk. The information industry is very competitive, and although disk drives still have an important role to play, rotating memory systems are being developed very fast. Those countries with a strong semiconductor industry are in a strong position; those weak in semiconductor technologies need a new technological edge to survive. The next 10–20 years will be very interesting indeed if we consider the developments in the postwar period.

Policies, Measures and Commitment

Understanding the forces of technical change associated with the introduction of new information technologies in developing countries involves different concepts and analysis. Information systems do not lend themselves very easily to conventional analysis, such as cost benefit. The conclusion can be very different depending on what position you take to analyze the situation. However, I believe it is important not to treat such change as a "black box" phenomena—something that exists outside the realm of the socioeconomic system—rather new information-communication technologies should be conceptualized as part of the environment they operate in and may be looked at as social systems in which technology is merely one dimension of such systems. This social systems paradigm for information technology has been explored in developed countries such as England, and it results in methodologies applicable to different organizations, contexts, and cultures (Walsham, Symons, & Waema 1988). It is particularly pertinent to the developing country situation because the social system paradigm implies that information-communication technology in a developing country can best be understood in terms of the local environmental conditions in which transfer takes place. In this sense technology is a neutral tool, but application can lead to both positive and negative effects. Exchange of information about adoption time is important to avoid duplicating mistakes. The lesson for information practitioners involved in the transfer of new technologies is to sensitize themselves to the cultural, political, and social problems under which they operate (Walsham, Symons, & Waema 1988, p. 202), a point also made by other writers (Stone 1985). The social systems approach can be approached through use of web models, which can provide elemental structure for information systems and networks to deal with infrastructural problems.

Developing countries, therefore, have to opt for the technology of the present that will best solve their own particular set of priorities, and, in doing so, must put in place all the component parts to sustain the technology. This immediately raises the broader question of how far one should expect a developing country to go in maintaining sustainability in technological change. How important should it be to emphasize national planning in the transfer of information-communication technologies? Should there be a case for the establishment of information industries in poorer countries of the South? For creation of semiconductor industries, software development, and value added communication services to ensure access to information at reasonable cost?

Some analysts (Stover 1984) have argued strongly for developing countries to set such goals of self-reliance, thereby reducing the dependency on the industrialized countries of the North by creating the conditions to produce their own hardware and software. This approach departs from the "trickle down concept" of technology to a "stock" concept and have paid a high price in poor performance (Dahlman 1987, p. 769). We should consider to what extent new technology developed in the North needs to be adapted and if local technologies can be a viable alternative. Two cases spring to mind in this context. China, after the Revolution in 1949 developed a vigorous policy of self-reliance linked with stringent isolation from all Western technology. Although this policy evolved out of the bitter experiences China had with the imperialist powers immediately prior to the Communist Revolution, it must be noted at varying periods throughout her long history, China has embraced foreign innovations only later to eschew Western technology. However, the policy of self-reliance reached its apex during the Cultural Revolution (1966–1976). During this period, an era marked by intense developments outside of China in the information industries, China lost a generation of experience and in spite of a vigorous program to catch up and develop a modern information industry. The standard of information communication is generally thought to be at least 10 years behind that of the United States and Japan in terms of hardware and 20 years or more in software applications to China's problems (See Broadbent 1980). India is often cited as an example of a developing country which has been able to develop its information industries in response to the principles of self-reliance. However, India has always adapted a pragmatic approach to technology. The importance of new technology to economic development has been emphasized in various national plans. Moreover, there has never been a policy of total self-reliance as in China. India has merely regulated the imports of foreign technology through a series of mechanisms such as licensing agreements which monitor foreign exchange, attempt equitable distribution, prevent monopolization, and foster indigenous development. This is a complex task for a country so large and diverse as India and it is difficult, without evidence from specific studies, to ascertain the effect of India's policies on technology imports though general accounts seen to indicate a degree of success (Piyush Kanfi Mahapatra 1983). In the 1950s, many developing countries chose this route in order to permit infant new technologies to grow until strong enough to compete with industries in more advanced countries. The effectiveness of such policies proved to be far from unqualified successes. Studies of Ghana in 1964 indicated 22 out of 31 new technology industries suffered massive losses (Griffin and Enos 1970).

For the majority of countries in the developing world, the information industries will remain an underdeveloped sector for some time to come, but which, I believe, should be stimulated further to help the development process.

Aside from questions of self-sufficiency and protectionist policies, it has been said that countries lacking a semi-conductor industry should not attempt to build computers. Ghana has been cited as an example of what can happen. Nevertheless situations change. Ghana has now eschewed the centrally planned economy model for establishing a new industrial base in favor of a more pragmatic approach that has involved freeing up some of the government bureaucracy where responsibility formerly lay in several ministries, has improved the decision-making process, but almost all its industry and service industries are located in a single city, Accra, choked with bad transportation and service industries. Ghana has been severely hit by the brain drain, but is now bounding back. To deal effectively with the real world situation, it is doubtful Ghana or any other African country could afford to stake the up-front costs matched by Singapore whose current technology center required an initial investment of US $7.6 million. Singapore, moreover, is in a unique position to mix knowledge with talent. The development of information-communication technologies does not come in tidy packages that fit traditional economies. What works in Singapore will not necessarily work in Ghana. Institutions in developing countries must learn to share information and technical abilities widely across traditional barriers and systems. A particular area of concern is the problem of communication between information experts and those in supporting technologies. Improved communication across professions should be used as a first step to build better infrastructure.

Economic theory presumes that all alternative ways of producing something are known. What is known in detail are the production processes in use. We tend to know less about alternatives. These differences in degrees of information are crucial, because the degrees of information are the important components to fill the gaps in the production function. It is a case of the old proverb "A little learning being a bad thing!", there being a basic amount of knowledge less than which cannot reasonably be acted upon. Everything depends upon the recipient of the new technology. If the recipient knows very little, they can do very little even with a basic knowledge because it is difficult to generate the complex detail that is often required to execute the total skill in the new technology. On the other hand, those who know a great deal and are capable of dealing with the complex details, can from just a small amount of information on the new technology act competitively on the rest. That is why it is hard to transfer new technology to many developing countries and not at all hard to transfer it to Japan.

In every economy, markets are imperfect. This is particularly true of developing country markets. There are big gaps in inputs where *input* is defined in this context to include information and motivation. This is where private entrepreneurs come in. They are energetic gap fillers and are a major factor in the information process where they apply knowledge and ideas to action. Activities in this information process at the technical transfer level involved the use of more skills, because not all aspects of new information technologies are easily transferable with any degree of ease. Five criteria can be identified in the transfer process, listed in order from the easiest to the most difficult:

(1) Equipment
(2) Services
(3) Skills
(4) Motivation
(5) Management

Developing countries having the least competence, and infrastructures should consider this transfer process in the reverse order to be most successful.

There are big differences between countries everywhere when one considers technical capacity. Emphasis is required, therefore, on such issues as investment policy as well as science policy—in absolute terms the human and financial capacities of developing advantage for most efficient adoption of new technologies. Investment in local R&D, education, and service sectors in developing countries remains weak because the need to absorb new technology requires a greater proportion of effort in the form of funds for training and R&D. This is demonstrated clearly by the big differences between developed and developing countries investment level. In order to increase absorptive capacity for efficient transfer of new technology, it is necessary to put in place services and staffs to apply the technology. Developing countries on the whole are not doing this and, as shown in Table 3, it is especially not being done in Africa. They are spending less and less on investments to increase their absorptive capacity.

Apart from self-help and new domestic policy measures, the process can be speeded up by international cooperation especially South–South cooperation, which would develop and promote national capability for the production and utilization of local information technologies and mutual sharing of software applications between countries to avoid duplication of effort. Specifically, this solution might include such things as regional directories of experts, joint research projects, exchange of experts, seminars, conferences and workshops, and joint efforts on such issues as compatibility and standards.

Summary & Conclusions

This article has considered the impact of new information technologies on developing countries. It has argued that modern information-communication technologies are not different from any other new technology in the economic order. It is, therefore, appropriate to consider the transfer process from industrial countries in the light of historical experiences. History teaches us that developing countries began to miss out on the industrial revolution at a very early age, and since then, the gap has been growing at an alarming rate. Concentration of the information industries lies in the richer countries of the North while the most urgent issues in applied technology require solutions in the

Table 3
Indicators of Technical Capacity

Indicator (% of World Total)	Industrial Countries	Developing Countries		
		Asia	Africa	Latin America
R&D scientists	55.4	1.2	1.4	2.0
R&D expenditures	66.5	0.31	1.60	0.94
Share of exports of capital goods	89.9	0.04	2.6	0.68
Developing country imports	90.3	0.1	5.1	0.53

Source: UNCTAD Handbook of International Trade & Development Statistics 1986 supp. UN Geneva. World Bank Development Reports.

poorer South. Without access to new information technologies adapted to local needs, the developing countries will fall farther and farther behind in world development. Various theories have been examined that suggest solutions. But without changes in policies at the national level that set agendas and priorities for information infrastructure, there is little hope for success. Donor agencies can assist with programs to build institutional capacities and provide seed money for national information infrastructure, but it is important to reject any "Bank-aid" solutions which some have suggested, including donating obsolence information tools to developing countries along with the experts to operate them. Developing countries must create their own programs from mandated national policies closely aligned to a science policy. It is strongly suggested that it is unrealistic for some poorer countries to act independently and build comprehensive information systems. The route to be taken lies in regional cooperation and information sharing among groups of countries working to solve similar problems. This South-South collaboration should also benefit from judicious support of industrial countries in the application of new technologies deemed appropriate in consultation with the developing countries.

The issue in question is our ability for social creativity, for information sharing, and technical collaboration. We have discussed how the new information-communication revolution can exacerbate disparities, but it also holds out a great deal of promise for equitable growth in the area of North-South relations. It requires an effort to make the new technology serve the interests of developing countries in an ever increasing interdependent world.

This requires us to assist, where possible, in the transfer of new information-communication technologies to developing countries by first understanding the processes of technical change in the social context, thereby avoiding many of the mistakes of the past. In this way, new technologies can be the effective tools they are meant to be when placed correctly into an acceptable infrastructure carefully aligned to local needs and priorities.

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